VI. *Directions for uſing the common Micrometer, taken from a Paper in the late Dr.* Bradley's *Hand-writing; communicated by* Nevil Maſkelyne, *Aſtronomer Royal, and F. R. S.*

Read Feb. 20, 1772.

MICROMETERS, as firſt contrived, being only adapted to the meaſuring ſmall angles, as the diameters of the Sun and Moon, or other planets, and taking the diſtance of ſuch objects as appeared within the aperture of the teleſcope at the ſame time, were not of ſo general uſe as thoſe which are contrived not only to anſwer the ends that the firſt inventers aimed at, but likewiſe, to take the difference of right aſcenſion and declination of ſuch objects as are farther aſunder than the teleſcope will take in at once, but which paſs through the aperture of it at different times. Mr. Caſſini firſt made uſe of threads interſecting one another at half right angles for determining the difference of right aſcenſions and declinations of objects near the ſame parallel; and this apparatus being ſimple and eaſily procured is of very great uſe to ſuch as are not provided with a micrometer made according to the late improvements. But, where ſuch a one is at hand, that method however curious need not be made uſe of, the micrometer

meter ſerving for the ſame purpoſe with greater exactneſs. It was for this reaſon indeed that the late alteration in the form of the micrometer was made, they being before not ſo convenient for making ſuch ſort of obſervations, both hairs being uſually moveable, and no proviſion being made for ſetting the hairs parallel to the diurnal motion of the objects to be obſerved; both which inconveniencies are avoided in the preſent micrometers.

The micrometer, as now contrived, is not only of uſe in meaſuring ſmall angles or diſtances between ſuch objects as appear within the aperture of the teleſcope at the ſame time, but likewiſe in taking the difference of right aſcenſion and declination between ſtars and planets, &c. which in their apparent diurnal motion follow one another through the teleſcope if kept in the ſame ſituation. In making the firſt kind of obſervations, turn the ſhort tube which carries the eye glaſs and micrometer, &c. till the croſs thread (or that which cuts the parallel threads at right angles) lies parallel to a line paſſing through the objects whoſe diſtance is to be meaſured, and then by raiſing or depreſſing the teleſcope by help of the ſtand bring the objects to appear upon or near the croſs thread, and one of them juſt to touch the fixt parallel thread: then turn the index of the micrometer till the moveable thread touches the other object, and the number of revolutions and parts of a revolution ſhewn by the index, turned into minutes and ſeconds by the table made as hereafter directed, will be the apparent angular diſtance of thoſe objects. It is here ſuppoſed, that the threads exactly cloſe, ſo as to touch each other when the index ſtands at the beginning of the diviſions: for, if they do not, there muſt be an allowance made in every obſervation; to avoid which, it is always beſt to adjuſt the threads to the beginning of the diviſions when they are firſt put on; for which purpoſe the holes in the little plate which carries the moveable thread are made oblong to give room to move it as occaſion requires, before it is pinched hard by the ſmall ſcrews which faſten it to the moveable arm, through which the long ſcrew paſſes. The other parallel thread, which I call the fixed one, muſt be firſt adjuſted by ſetting its edge exactly over the two marks made on each ſide the ſhort diameter of the aperture in the broad plates, and the croſs thread muſt be likewiſe ſet to agree with the ſtrokes made on each ſide the longeſt diameter, and then the interſection of the croſs thread and the fixt parallel one will be the center of the motion given to the outer plate of the micrometer (to which the great ſcrew index and threads are faſtened) by the worm, by turning of which the fixt parallel thread may eaſily be made to lie parallel to the apparent motion of any object in order to take the difference of declination and right aſcenſion from any other that follows through the aperture of the teleſcope.

This contrivance is of very great uſe to make a ſtar, &c. move true along the fixt parallel thread, which is abſolutely neceſſary in order to take the true difference of right aſcenſion and declination between it and any other that follows. Without this contrivance it is very difficult to make a ſtar move exactly upon the thread, and it can only be done by repeated trials, which may ſometimes take up a great deal of time.

If therefore a ſtar is made to move on the parallel thread juſt at the croſs, and (the teleſcope continuing fixt in the ſame poſition) it is afterwards near its going out of the aperture found not to be upon the thread, that muſt then be brought to the ſtar by the help of the worm, and then the thread will lie parallel to the diurnal motion of the ſtar in that part of the heavens, and conſequently the croſs thread will repreſent a meridian, and the others parallels of declinations, and the difference of time between the paſſage of the ſtar at the croſs wire (which was made to move along the thread), and the tranſit of any other ſtar, &c. over the croſs thread which repreſents a meridian, turned into degrees and minutes, will give the difference of right aſcenſion And, if the moveable parallel thread be brought, by turning the index, to touch the other ſtar about the time of its paſſage over the croſs thread, then the number of revolutions and parts ſhewn by the index (turned into minutes and ſeconds of a degree by the table) will be the difference of declination between the two ſtars. If the ſtar is made to paſs along the fixed thread ſo as to ſeem perfectly biſected, there muſt be an allowance made for the ſemidiameter of the thread or wire, becauſe I ſuppoſe the index to be adjuſted as before to the inner edges of the wires; but it may, if it is found convenient, be adjuſted to the middle of the threads, or elſe correction may be made in the obſerved diſtance.

In taking any angle, it is convenient that each of the parallel threads be about the ſame diſtance from the middle of the aperture of the eye-glaſs; and for this reaſon the whole micrometer is contrived to ſlide to and fro, as the caſe requires. The ſame motion is alſo of uſe in taking the difference of right aſcenſion and declination, by ſliding the fixt parallel thread (on which the preceding ſtar is brought to move) towards one ſide of the eye-glaſs; for by that means a greater angle may be taken in between the parallel threads, if need be. And it muſt always be remembered that the moveable parallel thread ſhould be ſet either north or ſouth of the other, according as the following ſtar is expected to be really ſouth or north of the preceding.

In making an obſervation, either the inner or the outer edges or the middle of the wires may be brought to touch the objects; but then, it muſt be remembered to allow ſomething for the thickneſs of the wire, in caſe the obſervation be not made from that part to which the index is adjuſted. In obſerving the diameters of the ſun moon or planets, it may perhaps be moſt convenient to make uſe of the outer edges of the threads, becauſe they will appear moſt diſtinct when quite within the limb of the planet; &c. but if there ſhould be any ſenſible inflection of the rays of light in paſſing by the wires, this would be beſt avoided by uſing the inner edge of one wire and the outer edge of the other. And in taking the diſtance or difference of declination between two ſtars, &c. the middle of the threads may perhaps be moſt convenient: but, however the obſervation is made, due correction muſt be allowed for the thickneſs of the wire, if requiſite.

The difference of declination of two ſtars, &c. may be obſerved with great exactneſs, becauſe the motion of the ſtars is parallel to the threads; but in taking any other diſtance, the motion of the ſtars being oblique to them is a great impediment, becauſe if one ſtar be brought to one thread before the eye can be directed ſo as to judge how the other thread agrees to the other ſtar, the former muſt be ſomewhat removed from its thread, ſo that in this ſort ot obſervations the beſt way of judging when the threads are at the proper diſtance is by frequently moving the eye backwards and forwards from one to the other: this method muſt chiefly be made uſe of when the diſtance of the objects is pretty large, and the motion or rowling of the eye great.

The micrometer is ſo contrived that it may be applied to teleſcopes of different lengths; but then, there muſt be a table for each teleſcope, by which the revolutions of the ſcrew may be turned into minutes and ſeconds of a degree. In order to this it is neceſſary that the threads of the micrometer ſhould be placed exactly in the common focus of the object-glaſs and eye-glaſs, that is, where the images of objects ſeen through the teleſcope are diſtinctly formed. The readieſt way of doing this is, firſt to ſlide the micrometer into the grooves fixt to the ſhort braſs tube, which carries the whole apparatus of eye-glaſs, &c. and then to draw the eye-glaſs out by means of its ſliding work, till the threads of the micrometer are in its focus, which is known by their appearing moſt diſtinct, &c. Then thruſt the ſhort tube before-mentioned into its proper place, as far as the ſhoulders of the braſs work will admit, and place the object glaſs in its cell, and looking through the teleſcope at ſome very diſtant object ſlide the wooden tube in or out till you make the object appear moſt diſtinct, or till it has the leaſt motion upon the threads when the eye is moved to and fro; for then the threads of the micrometer will be in the common focus of both glaſſes, and that will be the proper diſtance that the object-glaſs ought always to be at from the threads; and there ſhould be made ſome mark or ketch in the wooden tube in order to ſet it always at the ſame diſtance.

The proper diſtance of the threads from the object-glaſs being thus ſettled, the table for turning the revolutions, &c. of the ſcrew into angles or minutes and ſeconds of a degree may be made ſeveral ways; but as good and eaſy a method as any is carefully to meaſure how many inches and parts of an inch the object-glaſs is diſtant from the threads, and with the ſame ſcale to find alſo how many inches and parts of an inch an hundred, &c. revolutions or threads of the ſcrew of the micrometer are equal to: then, making the firſt diſtance radius, the laſt will be the ſine or tangent of an angle anſwering to 100 revolutions. And having the angle anſwering to 100 revolutions, the angle for any other number will be eaſily known and ſet down in the table, as alſo the parts of a revolution; for in ſmall angles, ſuch as can be obſerved with the micrometer, their ſines tangents or cords are nearly in the ſame proportion with the angles themſelves. The diſtance before-mentioned (to be uſed as radius) ought ſtrictly to be taken from the threads to a point

point within the object glaſs about one third of its thickneſs from that ſurface which is towards the wires, if the glaſs be, as uſual, equally convex on both ſides; but if the focus of the object-glaſs is pretty long and its thickneſs not great, the error that can ariſe by meaſuring from any part of the object-glaſs will become inſenſible as to the alteration in the angle.

The table for the micrometer may likewiſe be made by ſetting up two marks at a diſtance on the ground, and obſerving with the micrometer the revolutions, &c. which they ſubtend when ſeen through the teleſcope, and then computing the angles thoſe objects ſubtend at the object-glaſs, by meaſuring their diſtance from each other and from the object-glaſs. The like may alſo be done by opening the threads to any number of revolutions, and then making a ſtar move exactly upon the perpendicular thread, and noting the time it is paſſing from one parallel thread to the other; for that time turned into minutes and ſeconds of a degree, by allowing for the ſtar's declination and going of the clock, &c. will be the angle anſwering to the number of revolutions; from which the whole table may be made. This method perhaps might be moſt advantageouſly practiſed in ſtars near the pole, where the apparent motion being ſlow a ſecond in time will anſwer to a much ſmaller angle than towards the equator. But I believe, upon trial, the firſt method will be found moſt eaſy and practicable, eſpecially if the ſcale made uſe of be well divided.